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(54) Title: ELECTRONICALLY COMMUTATED MOTOR FOR DIRECT DRIVE OF WASHING MACHINE DRUM			
(57) Abstract			
<p>The invention concerns an electronically commutated motor for direct drive of a washing machine drum, wherein the rotor (2) is fixed directly to the driving shaft of the drum, with the stator (1) being fixed to the cross-shaped support of the drum. The structure of an electronically commutated motor for direct drive of a washing machine drum makes it possible, through an optimal stator pole (6)/intermediate space (10) width ratio, and with an uneven air gap (8) between the stator (1) and the rotor (2), to achieve a low noise level and a relatively high moment at the motor shaft. The number of rotor poles represented by magnetic segments (3) is greater than the number of stator poles (6) with coils (4), the rotor poles/stator poles ratio factor equalling 1.3333, and the stator pole (6)/intermediate space (19) width ratio between the stator poles (6) equalling 1.868.</p>			

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**ELECTRONICALLY COMMUTATED MOTOR FOR DIRECT DRIVE OF
WASHING MACHINE DRUM**

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15 The invention concerns an electronically commutated motor for direct drive of a washing machine drum, wherein the rotor is fixed directly to the driving axle of the drum, and the stator is fixed to the cross-shaped support of the drum. The invention belongs to the IPC class H02K 7/00.

20 The technical problem, which has been successfully solved by the present invention, is how to build a driving motor for a washing machine drum that will provide direct drum driving at low noise levels and a relatively high moment at the motor shaft.

- Washing machines widely use asynchronous or universal collector motors for driving the drum, which are installed under the drum. Power transfer from the motor to the drum is carried out by way of two pulleys and a belt with the usual gear ratio of 1:12. The described arrangement
- 5 has several drawbacks: high counterweight mass due to motor position outside the drum centre; high level of noise, particularly during the centrifuging stage; relatively short life expectancy of the belt; motor characteristic is unadapted to the load characteristic; and low yield of the drive.
- 10 All the above-mentioned drawbacks are eliminated through the design of a washing machine with direct drive of the drum. The stator of such motor is fixed to the cross-shaped support of the drum, whereas the rotor is mounted directly onto the driving axle of the washing drum. Thus the motor itself thus has no bearing of its own, as it uses the existing drum
- 15 bearing instead. In such a structure of the drive, the prior art two driving pulleys and the belt are no longer necessary, which means a considerable reduction of counterweight. In addition to the above-mentioned advantages, a direct drive also eliminates the previously enumerated drawbacks of the conventional drive of washing machine drums.
- 20 Motor versions have been known for direct drive of washing machines, which are usually equipped with a number of stator poles greater than that of rotor poles, resulting in strong pulsations of the shaft moment, and consequently, in a high noise level. The air gap between the rotor and the

stator is usually even, this providing an inter-phase induced voltage of trapezoidal form, which - at the usual current form - again leads to a relatively high noise level. An optimal stator pole/intermediary space width ratio should be chosen in order to obtain a low noise level and a relatively high moment at the machine shaft. In prior art direct drives this ratio is not optimal. With the conventional method of producing laminations, where the external and internal motor diameters are relatively large, there is a large quantity of scrap, which results in higher production costs of the motor. The prior art drives also use the conventional way of front and groove insulation, which is a time- and money-consuming process.

The structure of an electronically commutated motor for direct drive of a washing machine drum in accordance with the invention makes it possible - through an optimal stator pole/intermediate space width ratio and with an uneven air gap between the stator and the rotor - to obtain a low noise level and a relatively high moment at the motor shaft.

An electronically commutated motor for direct drive of a washing machine drum in accordance with the invention will now be described by way of example and with reference to the accompanying drawings in which:

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Figure 1 is a cross-sectional view illustrating a rotor and stator part;

- Figure 2** illustrates a stator assembly segment of a motor in accordance with the invention;
- Figure 3** illustrates a stator and motor part of a motor in accordance with the invention showing uneven air gaps;
- 5 **Figure 4** illustrates the production of a stator lamination;
- Figure 5** is a schematic presentation of different electrical connections of a motor for the different working operations of a washing machine;
- Figure 6** is a longitudinal cross-sectional view illustrating a motor in accordance with the invention;
- 10 **Figure 7** illustrates the magnetization of magnetic segments;
- Figure 8** illustrates stator poles.

An electronically commutated motor for direct drive of a washing machine drum in accordance with the invention comprises a stator 1 consisting of a stator assembly made of dynamo sheet including a stator frame 5 with stator poles 6 expressed along its periphery. Coils 4 are installed on said expressed stator poles 6, which represent a concentric three-phase stator winding. A rotor 2 of the motor is carried out as a soft-magnetic iron core 7 onto which magnetic segments 3 are bonded.

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The stator 1 of an electronically commutated motor in accordance with the invention is fixed to the cross-shaped support of the washing machine. The number of rotor poles represented by said magnetic segments 3 is

greater than the number of the expressed stator poles 6, the rotor poles/stator poles ratio factor equalling 1.3333.

An uneven air gap between the rotor and stator poles can be achieved in two ways. In the first case, the magnetic segments 3 of rectangular form
5 are bonded to the rotor core 7, with the upper surface of the stator poles 9 in the stator assembly 12 having a slightly convex shape, thus producing an uneven air gap 8. In the second case, the magnetic segments 3 can be shaped according to the radius, with the stator poles 9 being straight. Through an uneven air gap thus formed between the stator and the rotor,
10 a sinusoidal form of the inter-phase induced voltage is obtained which strongly reduces the noise level during motor operation. The stator pole 9/intermediate space 10 width ratio between the individual stator poles 9 equals 1.868. Such a ratio represents an optimal choice, since minimal turning moment pulsation is achieved through it along with a minimal noise
15 level.

A schematic presentation of electrical connections of the motor for the different washing machine operations is shown in Figure 4. The three-phase motor winding 19 is star connected, with each phase having two taps: one for washing and one for the centrifuge. During the washing
20 cycle, when lower rotational speed is needed, the motor is connected between terminals U1, V1 and W1. In this case the entire winding is active. During centrifuging, when high rotational speed is needed, the motor is connected between terminals U2, V2 and W2. In this position

only a part of the winding is active. The centrifuging/washing ratio of the active winding can be 1:3, 1:4 or 1:5. Said winding 19 with taps makes it possible for the motor to operate under optimal conditions through all washing cycles.

- 5 Figure 4 illustrates a part of production of a stator assembly. Individual stator laminations are cut out of a strip 11 and then formed by bending the cut-out strip to a pre-determined diameter. Two stator assemblies can be simultaneously cut out of the strip 11. The cut-out strips for the first stator assembly are bent in one direction, and those for the second assembly
10 are bent in the other direction. Simultaneously with the stator laminations also auxiliary grooves 13 are cut out of the strip, which will facilitate subsequent bending of the cut-out strip to the pre-determined diameter.

- The stator assembly itself is lined with plastic material which forms front insulation 14, groove insulation 15 and a hub 16 for the fixation of the
15 stator to the cross-shaped support of the drum.

 On the plastic lining of the stator assembly, places are provided for the fixation of circuits 17 of Hall generators - three in number - which lie in the centre of adjacent grooves, at an angular distance of 15° with regard to each other. The position of the circuits 17 is shown in Figure 1.

- 20 The magnetic segments 3 together with the iron core are also lined with plastic material 18 which, in addition to fixing the magnetic segments 3 to the iron core 7, also forms a hub for the fixation of the rotor 2 to the shaft of the washing machine drum.

Additional reduction of moment pulsations and thereby the reduction of noise are achieved through magnetization of magnetic segments 20 into a delta form, as shown in Figure 7, or by shaping stator poles 21 into a double trapezoidal form, as shown in Figure 8.

- 5 An electronically commutated motor for direct drive of a washing machine drum in accordance with the invention has successfully solved the set technical problem of direct drive of a washing machine drum with minimum moment pulsation and hence, with a low noise level and a relatively high moment at the motor shaft. In addition, the described
- 10 structural solution of a motor also provides the possibility of easy, large-series production.

CLAIMS

1. An electronically commutated motor for direct drive of a washing machine drum, wherein a stator (1) is fixed to the cross-shaped support
5 of the washing machine and a rotor (2) is fixed directly to the axle of the washing machine drum,

characterised in that

- the number of rotor poles represented by magnetic segments (3) is greater than the number of stator poles (6) with coils (4), the stator
10 poles/rotor poles ratio factor being 1.3333, whereas the stator pole (6) intermediary space (10) width ratio between said stator poles (6) is 1.868.

2. An electronically commutated motor for direct drive of a washing
15 machine drum as claimed in Claim 1,

characterised in that

- said magnetic segments (3) bonded to the rotor core (7) have a rectangular form, with the upper surface of stator poles (9) in a stator
assembly (12) being slightly convex, thus forming an uneven air gap
20 (8).

3. An electronically commutated motor for direct drive of a washing machine drum as claimed in Claim 1,

characterised in that

said magnetic segments (3) are shaped according to the radius, while said stator poles (9) are straight.

- 5 4. An electronically commutated motor for direct drive of a washing machine drum as claimed in Claims 1 to 3,

characterised in that

a three-phase winding (19) is star connected, with each phase having two taps, whereby in the first regime, the motor is connected between
10 the terminals U1, V1 and W1 with the entire winding being active, and in the second regime, the motor is connected between the terminals U2, V2 and W2, with a part of the winding being active, the ratio of the active windings between the first and the second regime being 1:3, 1:4 or 1:5.

15

5. An electronically commutated motor for direct drive of a washing machine drum as claimed in Claims 1 to 4,

characterised in that

a stator assembly (12) is made by cutting stator laminations out of a
20 strip (11), whereupon the stator assembly (12) is formed by bending the cut-out strip (11) to a pre-determined diameter.

6. An electronically commutated motor for direct drive of a washing machine drum as claimed in Claim 5,

characterised in that

two stator assemblies (12) are simultaneously cut out of a strip (11)
5 and formed by bending the cut-out strip (11) in one direction for the first assembly, and into another for the second assembly.

7. An electronically commutated motor for direct drive of a washing machine drum as claimed in Claims 5 and 6,

10 **characterised in that**

simultaneously with said stator laminations auxiliary grooves (13) are cut out of said strip (11).

8. An electronically commutated motor for direct drive of a washing machine drum as claimed in Claims 1 to 7,

15 **characterised in that**

said stator assembly (12) is lined with plastic material, this forming front insulation (14), groove insulation (15) and a hub (16) for the fixation of the stator (1) to the cross-shaped support of the drum.

20

9. An electronically commutated motor for direct drive of a washing machine drum as claimed in Claims 1 to 8,

characterised in that

in the plastic lining of the stator assembly fixation places are provided for three circuits (17) of Hall generators lying in the centre between the adjacent grooves (10) at an angular distance of 15° with regard to each other.

5

10. An electronically commutated motor for direct drive of a washing machine drum as claimed in Claims 1 to 9,

characterised in that

- 10 said magnetic segments (3) together with the iron core (7) are lined with plastic material (18), which at the same time forms a hub for the fixation of the rotor (2) to the shaft of the washing machine drum.

11. An electronically commutated motor for direct drive of a washing machine drum as claimed in Claims 1 to 10,

15 **characterised in that**

- magnetic segments (20) are magnetized to form a delta, whereas the stator poles are straight.

12. An electronically commutated motor for direct drive of a washing machine drum as claimed in Claims 1 to 10,

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characterised in that

- stator poles (21) are formed into a double trapezoidal form, whereas the magnetic segments are magnetized in a straight line.

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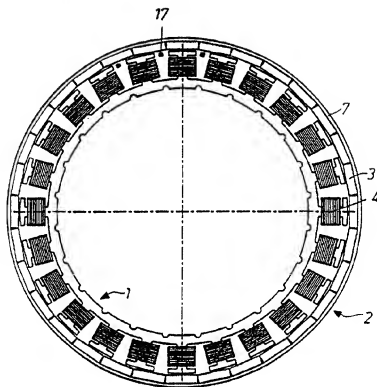


FIGURE 1

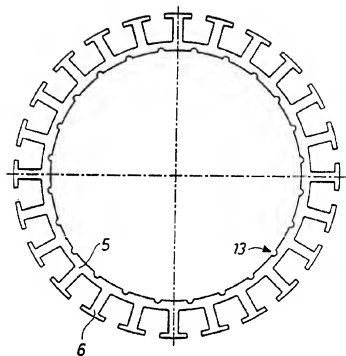


FIGURE 2

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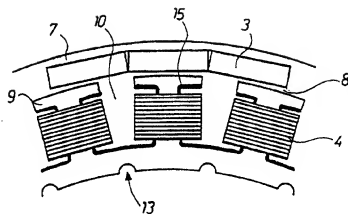


FIGURE 3

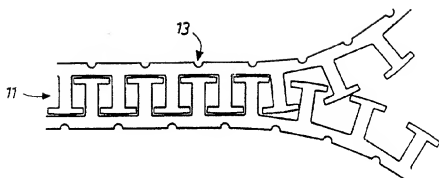


FIGURE 4

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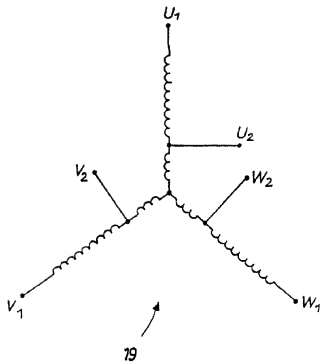


FIGURE 5

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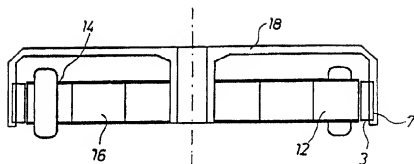


FIGURE 6

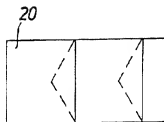


FIGURE 7

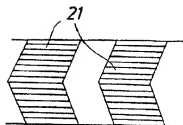


FIGURE 8

INTERNATIONAL SEARCH REPORT

International Application No.

PCT/SI 97/00021

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H02K29/03 D06F37/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H02K D06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 030 864 A (VAN HOUT HENRICUS M ET AL) 9 July 1991 see column 2, line 6 - column 3, line 6	1
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A	US 4 712 035 A (FORBES FRANKLIN L ET AL) 8 December 1987 see figures 2.3, 22	4-7



Further documents are listed in the continuation of box C.



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Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	US 5 489 811 A (KERN ROBERT ET AL) 6 February 1996 see figures 3,4 ---	5
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